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ORIGINAL RESEARCH

SHOULDER EXTERNAL ROTATOR ECCENTRIC TRAINING VERSUS GENERAL SHOULDER EXERCISE FOR SUBACROMIAL PAIN SYNDROME: A RANDOMIZED CONTROLLED TRIAL

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ABSTRACT

Background: Shoulder pain affects up to 67% of the population at some point in their lifetime with subacromial pain syndrome (SAPS) representing a common etiology. Despite a plethora of studies there remains conflicting evidence for appropriate management of SAPS.

Purpose: To compare outcomes, for individuals diagnosed with SAPS, performing a 6-week protocol of eccentric training of the shoulder external rotators (ETER) compared to a general exercise (GE) protocol.

Study Design: Randomized controlled trial

Methods: Forty-eight individuals (mean age 46.8 years +/–17.29) with chronic shoulder pain, and a clinical diagnosis of SAPS were randomized into either an experimental group performing ETER or a control group performing a GE program. The intervention lasted for six weeks, and outcomes were measured after three weeks, six weeks, and again at six months post intervention.

Results: The primary outcome of function, measured by the Western Ontario Rotator Cuff Index, demonstrated a significant interaction effect derived from a multilevel hierarchical model accounting for repeated measures favoring the experimental group at week 3: 14.65 ($p = .003$), Week 6: 17.04 ($p < .001$) and six months: 15.12 ($p = .007$). After six months, secondary outcome measures were improved for Numeric Pain Rating Scale levels representing pain at worst ($p = .006$) and pain on average ($p = 0.02$), external rotator ($p < .001$), internal rotator ($p = 0.02$), and abductor strength ($p < .001$). There were no statistically significant differences in secondary outcome measures of Global Rating of Change, Active Range of Motion, the Upper Quarter Y Balance Test and strength ratios after six months.

Conclusion: An eccentric program targeting the external rotators was superior to a general exercise program for strength, pain, and function after six months. The findings suggest eccentric training may be efficacious to improve self-report function and strength for those with SAPS.

Level of Evidence: 2b

Key Words: Eccentric Training, shoulder exercise, subacromial pain

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INTRODUCTION

Shoulder pain is prevalent, affecting up to 67% of community dwelling individuals and resulting in a significant loss of function and associated disability.[1] Chronic shoulder pain is also common with 46.7% of cases persisting after one year.[2] Although the etiology of shoulder pain is variable, a body of evidence has implicated subacromial pain syndrome (SAPS) as a primary source.[3,4] Symptoms arising from the subacromial space are thought to be the most common cause of shoulder pain comprising 44-65% of all reports.[5,6]

Exercise can be considered the standard of care and an accepted first line intervention for individuals experiencing SAPS.[7] Variations of exercise interventions for SAPS have demonstrated effectiveness including supervised exercise, unsupervised home program exercise, and multi-modal interventions provided by a physical therapist.[8] No significant, long term difference has been demonstrated between these various management approaches, however, efficacy of exercise over placebo treatment or no treatment has been established.[8] Moreover, when comparing exercise versus surgery for SAPS and rotator cuff tendinopathy no significant difference exists for pain and function at both short and long term follow up.[9,10] While a variety of exercise protocols demonstrating effectiveness exist, a clearly defined best method of resisted exercise has yet to be established. Exercise, as an intervention, has been found to benefit patients with SAPS, however, further study is needed due to the paucity of quality investigations examining specific shoulder resistance training programs.[8,11]

Eccentric training of shoulder musculature as an intervention for the management of SAPS has been examined in six published clinical trials to date.[12-17] The authors of these investigations have utilized a variety of training protocols, specific exercises, dosing strategies, experimental and non-experimental methodology. None of these investigations have targeted the external rotators in isolation but rather the shoulder abductors alone or in combination with the external rotators.[12,13,17] Exercises targeting shoulder abduction may improperly emphasize an existing abnormal deltoid to rotator cuff muscle imbalance, thereby further accentuating an underlying cause of SAPS.[18,19] Individuals with SAPS have been identified as having weakness of the shoulder external rotators compared to healthy controls.[20] The effects of eccentric training, of only the shoulder external rotators, in patients experiencing SAPS has not been studied in a randomized controlled trial. Moreover, limitations due to single arm designs,[14-16] a focus on eccentric loading of the shoulder abductors,[12,13] or a lack of appropriate load for the provided eccentric exercises[17] warrants further study of eccentric training to the shoulder external rotators.

Prior investigations for eccentric training of the shoulder abductors have primarily utilized a pain provocation model for exercise progression.[21] This method of progressing resistance training load and volume assumes that pain must be increased during the exercise movement for clinical benefit to occur. The contrast to this approach would be a performance based progression as utilized in the Blume et al.[17] study for shoulder eccentric training. This method progresses a patient based on the ability to perform a higher number of repetitions at a given load without increasing symptoms which could be favorable in many clinical settings. Optimal loading management has the potential for improving patient outcomes by strengthening the affected tendon tissue while concurrently creating a hypoalgesic affect.[22,23]

Further investigation on the role of eccentric training, specifically of the shoulder external rotators, in patients with SAPS is warranted. Thus, the purpose of this investigation was to compare outcomes, for individuals diagnosed with SAPS, performing a six-week protocol of eccentric training of the shoulder external rotators compared to a general exercise protocol.

METHODS

Participants

Forty-eight participants with SAPS (20 women, 28 men, mean 46.8 years (+ / – 17.29)), volunteered and qualified for participation in this clinical study. The presence of SAPS was determined by the presence of a positive result for at least three of the following criteria: the Neer impingement test, the Hawkins-Kennedy impingement test, the empty can test, pain with resisted external rotation, palpable tenderness at the insertion of the supraspinatus or infraspinatus,

or painful arc from 60° to 120° during active abduction.[24-26] Moreover, the onset of shoulder pain had to be greater than three months so only individuals with non-acute shoulder pain were included. Participants were recruited from the local community with publicly displayed flyers. Exclusion criteria were red flags noted in the patient's medical screening questionnaire, suspected full thickness supraspinatus or infraspinatus tendon tears as identified by a positive drop arm test,[24] external rotation lag sign[27] or rent test,[28] adhesive capsulitis as identified by multiple plane passive motion loss,[29] or history of shoulder surgery. The primary investigator enrolled all participants and conducted all outcome measure assessments while being blinded to group allocation. All participants signed an informed consent form approved by the institutional review boards from the University of St. Augustine and Nova Southeastern University. This investigation was registered with the United States National Institutes of Health (clinicaltrials.gov identifier: NCT02153827)

Outcome Measures and Procedures

Participants completed the primary outcome measure, The Western Ontario Rotator Cuff Index (WORC), as well as the Numeric Pain Rating Scale (NPRS) for worst pain, best pain, and average pain as a secondary measure.[30] Both the WORC and NPRS have been validated previously and demonstrate good to high reliability for individuals with shoulder pain (ICC's of .89 and .74 respectively).[31-34] Additional secondary outcome measures were tested in the following order: Isometric strength values, active range of motion (AROM), the upper quarter Y-balance test (UQYBT) and Global Rating of Change (GROC). Isometric strength values were measured using the microFET2© hand held dynamometer (HHD) (Hoggan Health Industries, West Jordan, Utah)[a] per the protocol described by Kolber et al.[35] Isometric external rotation, internal rotation and abduction strength were all tested with participants seated and supported by an armless chair. A stabilization belt was applied to the participant's torso to restrict movement during the tests. A stabilization device was used to restrict movement of the HHD during testing. Strength tests were performed in consecutive order for three repetitions, with an isometric hold time of approximately six seconds each. The participant was instructed to provide their best effort for the duration of the six second total time. Peak force for each trial was recorded in kilograms. A 10 second rest between trials occurred and the highest strength value of the three trials, for each position, was recorded. Mean peak strength levels were calculated and adjusted for bodyweight. Strength ratios were then determined by dividing the peak strength value of one measurement by the peak value from another measurement. High reliability of HHD (ICC = .97) has been established when using a stabilization device as described previously.[35,36]

AROM was tested with a standard 12-inch goniometer utilizing the procedures outlined by Riddle et al.[37] The motions that were tested include abduction, flexion, extension, external rotation and internal rotation. Participants were verbally and passively guided in the movement to be performed for one repetition prior to testing. Participants were then asked to perform the movement actively until limited AROM or pain was experienced. Good reliability (ICC .76-.91) of goniometry for shoulder AROM has been established in subjects with shoulder pain.[38]

The UQYBT was used to determine closed chain performance as described by Gorman et al.[39] with high reliability (ICC .90). The test was performed with the participant in the push-up position. Participants used a single arm to stabilize while the other arm performed a reaching motion in three directions, relative to the participants free hand. The participant moved the free hand as far as possible in the medial, superolateral and inferolateral directions. For each direction, the length of reach was recorded in centimeters. The participant was allowed three practice trials and then three testing trials were performed to determine the distance sum. Limb length was taken into consideration and normalized by taking the total excursion distance and dividing it by 3 times the limb length.

The GROC[40] was used to evaluate participant perceived change at week three, week six, and at the six-month follow up. This outcome measure asks the participant to rate their overall perception of improvement. The GROC contains a 15 point scale ranging from -7 "a very great deal worse", to 0 "about the same", to +7 "a very great deal better". A change

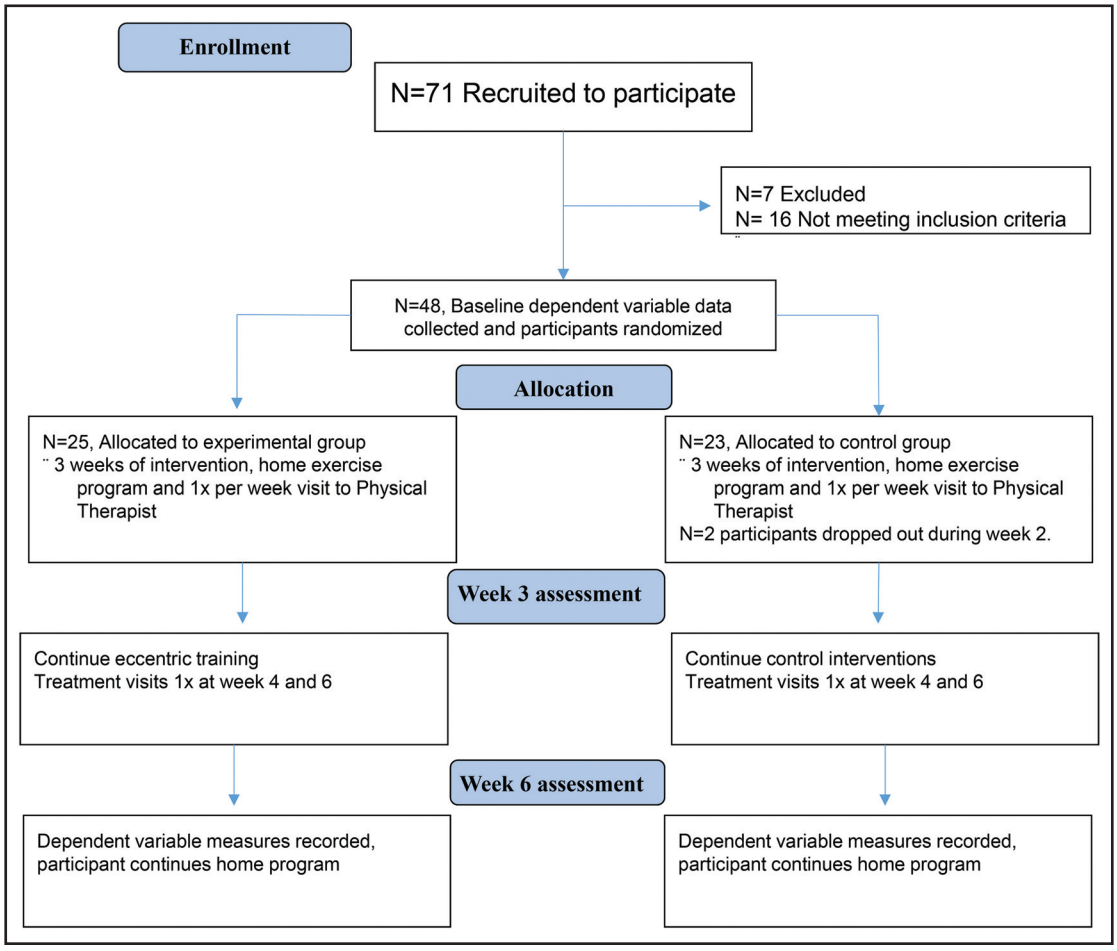

Figure 1. *Study Design Flow Diagram.*

of (+3) points on the GROC has been described as the minimal clinical important difference (MCID) and associated with meaningful improvement in a patients perceived quality of life.[40]

Interventions

The study design is outlined in (Figure 1). All participants were randomized to one of two exercise programs by blindly placing a pen on a table of random numbers[41] with odd numbers allocating the control group and even numbers allocating the experimental group. Each participant was seen by a physical therapist for a total of four treatment visits over six weeks. One program consisted of eccentric training to the external rotators (ETER) (Figures 2a and 2b) along with scapular retraction with a resistance band (Figures 3a and 3b) and posterior shoulder stretching exercises (Figure 4). The other program comprised of a general shoulder exercise protocol (GE) of active flexion, abduction, scapular retraction and posterior shoulder stretching exercises all into maximum tolerated range of motion without increasing symptoms. All participants maintained an exercise diary to record adherence to the home program. Both the treatment and control group interventions are shown in (Table 1).

The eccentric exercise used in this study was performed without an associated increase in resting symptoms. The *TheraBand*™ system of progressive resistance (The Hygienic Corporation, Akron, OH) was used to provide resistance for the eccentric exercises. Load was increased by resistance band thickness (color coded) from Green, Blue, Black, Silver, to Gold. Each participant was given a four-foot length band and instructed to use it for the home program. The starting position was established by the participant standing just far enough away from the anchor point so that no slack remained in the band. If a participant reported an increase in pain from rest

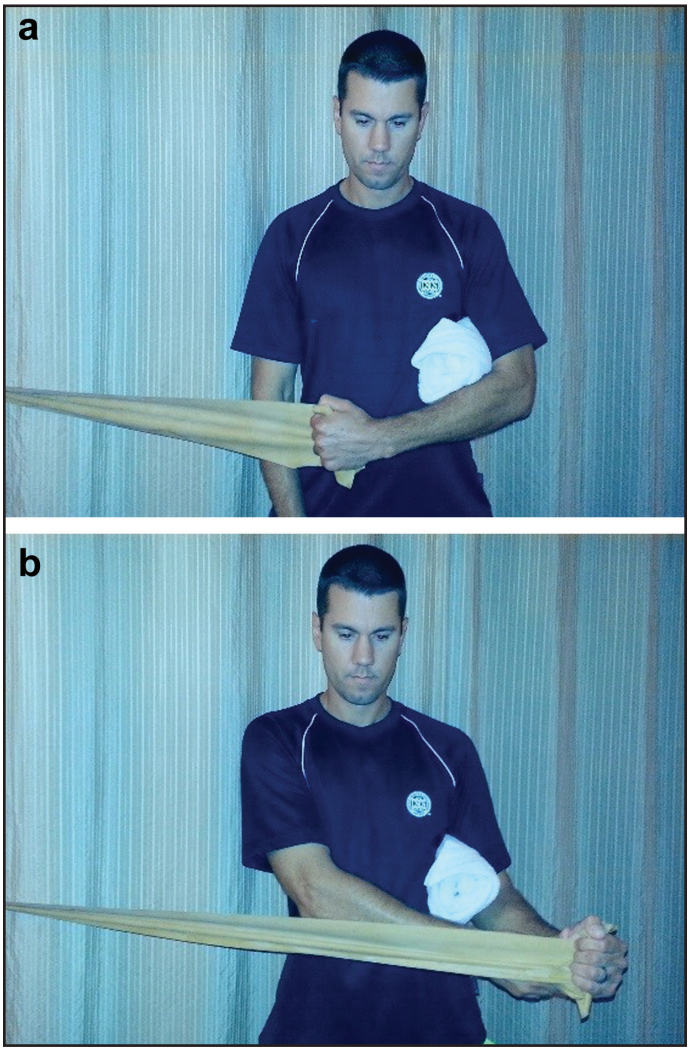

Figure 2. *Standing eccentric training of the external rotators exercise, a) start position, b) end position. Resistance band tension is standardized so that the starting position begins with all slack taken out of the band. The contralateral arm assists in the concentric phase to maximum available external rotation. A 2 second isometric contraction is held at end-range before a slow 3 second eccentric return to the starting position.*

while performing the exercise a reduced load was prescribed until the pain level was the same or less compared to resting pain levels. To perform each repetition only eccentrically the contralateral arm assisted the exercising arm through the concentric portion to achieve the end range external rotation position. Dosing of the eccentric external rotation exercise consisted of 3 sets of 15 repetitions each performed with the eccentric phase lasting three seconds in duration. Load was prescribed by the appropriate band thickness so that volitional muscle

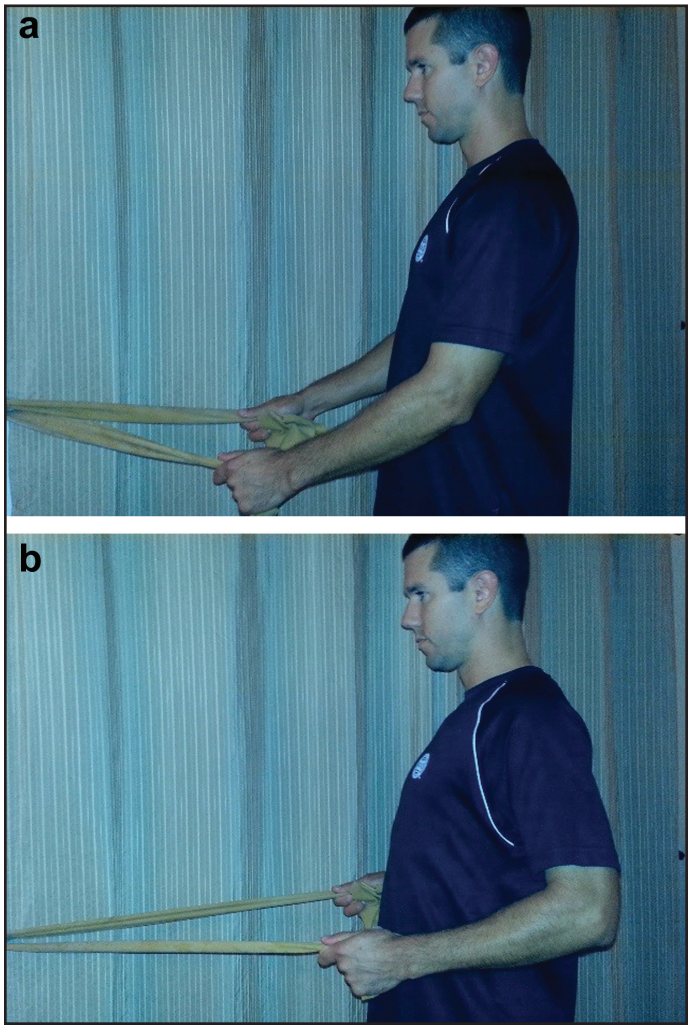

Figure 3. *Standing scapular retraction exercise, a) start position with no slack in resistance band, b) end position with maximum scapular adduction.*

Figure 4. *Cross body posterior shoulder stretch consisting of horizontal adduction of the affected shoulder with contralateral arm assistance to hold the sustained stretch.*

Table 1. *Treatment and control group interventions.*

Experimental Group Interventions		Control Group Interventions	
Exercise	**Dose**	**Exercise**	**Dose**
Eccentric external rotator with 3 second eccentric phase using resistance band	3 sets of 15 repetitions performed once daily	Active range of motion in standing with no resistance for flexion in the sagittal plane and abduction in the coronal plane	2 sets for 10 repetitions each once daily
Scapular retraction using resistance band	2 sets of 10 repetitions performed once daily	Scapular retraction using resistance band	2 sets of 10 repetitions once daily
Cross body horizontal adduction stretch in the standing position	3 repetitions, 30-45 seconds each performed once daily	Cross body horizontal adduction stretch in the standing position	3 repetitions, 30-45 seconds each once daily

Table 2. *Baseline descriptive statistics.*

Descriptive Characteristics	GE Group (N=23)	ETER (N=25)	p value†
Age (years)	48.35 (16.89)	43.35 (17.88)	.550
Body mass (kilograms)	81.90 (18.55)	79.87(15.04)	.677
Pain onset duration (months)	44.91 (75.51)	53.36(84.67)	.715
Best Pain (NPRS)	1.22 (1.28)	1.64 (1.71)	.396
Average Pain (NPRS)	3.30 (1.61)	3.72 (2.03)	.572
Worst Pain (NPRS)	7.00 (2.09)	7.00 (1.78)	.673
WORC	65.40 (14.08)	66.63 (15.95)	.741
External rotation strength (BWKG)	.130 (.029)	.133 (.024)	.665
Internal rotation strength (BWKG)	.141 (.036)	.168 (.059)	.062
Abduction strength (BWKG)	.146 (.064)	.185 (.071)	.052
IR/ER ratio	1.100 (.237)	1.243 (.295)	.067
ABD/ER ratio	1.098 (.367)	1.360 (.352)	.015*
Flexion AROM (degrees)	148 (31)	154 (15)	.395
Abduction AROM (degrees)	149 (35)	149 (30)	.988
External rotation AROM (degrees)	79 (17)	82 (13)	.425
Internal rotation AROM (degrees)	60 (16)	59 (14)	.887
Medial UQYBT (cm/limb length)	1.052 (.203)	1.120 (.193)	.244
Superior lateral UQYBT (cm/limb length)	.546 (.177)	.648 (.189)	.060
Inferior lateral UQYBT (cm/limb length)	.614 (.131)	.712 (.156)	.023*

NOTE. Values are mean (SD). Abbreviations: GE=general exercise; ETER= eccentric training of the external rotators; NPRS= numeric pain rating scale; WORC= Western Ontario rotator cuff index; BWKG= kilograms of force adjusted for bodyweight; IR/ER ratio= ratio of external rotation strength to internal rotation strength; ABD/ER ratio= ratio of external rotation strength to abduction strength; AROM= active range of motion; UQYBT= upper quarter Y-balance test.

*Statistically significant, †*P* values obtained from Mann Whitney U for NPRS and WORC, Independent samples *t* test for all others.

Table 3. *Mean values for patient-reported function, global change, pain, external rotation strength, internal rotation strength, abduction strength (all strength outcomes adjusted for body-weight), ABD/ER and IR/ER.*

	GE Group				ETER Group			
Outcome measure	Week 0 (N=23)	Week 3 (N=21)	Week 6 (N=21)	6 Month (N=14)	Week 0 (N=25)	Week 3 (N=25)	Week 6 (N=25)	6 Month (N=22)
WORC	65.40 (14.08)	64.17 (16.30)	70.56 (16.76)	77.15 (15.91)	66.63 (15.95)	78.81 (12.37)	87.60 (14.45)	92.72 (8.98)
GROC	NA	+.17 (2.06)	+1.17 (2.50)	+2.50 (2.65)	NA	+2.64 (2.30)	+4.44 (1.91)	+5.00 (2.25)
Best Pain NPRS	1.22 (1.28)	1.43 (1.44)	1.13 (1.25)	1.00 (1.30)	1.64 (1.71)	.76 (1.20)	1.00 (1.47)	.54 (1.18)
Average Pain NPRS	3.30 (1.61)	3.26 (1.88)	2.70 (2.03)	2.14 (1.83)	3.72 (2.03)	2.44 (2.14)	1.40 (1.68)	1.04 (1.62)
Worst Pain NPRS	7.00 (2.09)	6.65 (2.20)	6.39 (2.55)	5.21 (2.19)	7.00 (1.78)	5.24 (2.35)	3.88 (2.40)	3.32 (2.91)
ERS	.130 (.029)	.122 (.031)	.119 (.030)	.123 (.032)	.133 (.024)	.153 (.038)	.156 (.038)	.171 (.046)
IRS	.141 (.036)	.136 (.037)	.132 (.030)	.143 (.045)	.168 (.059)	.181 (.064)	.182 (.066)	.203 (.072)
AbdS	.146 (.064)	.139 (.058)	.138 (.042)	.142 (.051)	.185 (.071)	.188 (.068)	.200 (.069)	.228 (.084)
ABD/ER SR	1.09 (.36)	1.12 (.32)	1.15 (.25)	1.15 (.33)	1.36 (.35)	1.23 (.26)	1.28 (.27)	1.33 (.32)
IR/ER SR	1.10 (.23)	1.15 (.28)	1.14 (.30)	1.16 (.22)	1.24 (.29)	1.19 (.33)	1.17 (.33)	1.18 (.23)
Flexion AROM	148 (31)	151 (24)	162 (16)	170 (15)	154 (15)	158 (14)	167 (13)	175 (11)
Abduction AROM	149 (35)	150 (36)	158 (26)	167 (25)	149 (30)	157 (29)	168 (19)	176 (7)
ER AROM	79 (17)	77 (16)	78 (14)	82 (18)	82 (13)	82 (13)	86 (7)	89 (6)
IR AROM	60 (16)	59 (13)	58 (13)	64 (10)	59 (14)	60 (16)	63 (6)	68 (8)
Medial UQYBT	1.05 (.20)	1.02 (.22)	1.00 (.28)	1.12 (.29)	1.12 (.19)	1.15 (.21)	1.20 (.23)	1.21 (.13)
Superior/Lateral UQYBT	.54 (.17)	.50 (.14)	.50 (.15)	.56 (.18)	.64 (.18)	.66 (.14)	.68 (.15)	.66 (.10)
Inferior/Lateral UQYBT	.61 (.13)	.58 (.15)	.53 (.13)	.57 (.13)	.71 (.15)	.72 (.12)	.71 (.11)	.66 (.10)

NOTE. Values are presented as mean (SD). Units of measurement: Strength measured as peak force divided by bodyweight in kilograms, AROM measured in degrees, UQYBT reach distance divided by limb length in cm.

Abbreviations: GE= general exercise; ETER= eccentric training of the external rotators; WORC= Western Ontario rotator cuff index; GROC= global rating of change scale; NPRS= numeric pain rating scale; NA= not applicable; ERS= external rotation strength; IRS= internal rotation strength; AbdS= abduction strength; ABD/ER SR, external rotation abduction strength ratio; IR/ER SR, external rotation internal rotation strength ratio; AROM= active range of motion; ER= external rotation; IR= internal rotation; UQYBT= upper quarter Y-balance test.

Table 4. *Pairwise comparisons of mean differences for each WORC time point..*

Time point	Mean difference between groups	Standard Error	p value
Week 3	14.65	4.18	0.003
Week 6	17.04	4.18	<0.001
6 Month	15.12	4.69	0.007

Note: Results describe the interaction effect derived from a multilevel hierarchical model accounting for repeated measures. Post hoc testing for pairwise comparisons were performed using Tukey correction.

failure of the external rotators occurred between 15 and 18 repetitions.

Data Analysis

With an effect size of .40 for the primary outcome measure WORC, significance level of $p < .05$, statistical power set at $P = .80$, it was estimated that a total study sample size of 48 participants were needed for this study. Baseline between group differences for all outcome measures and demographics were analyzed using the independent samples *t*-test. The non-parametric Mann-Whitney U test was used to analyze between group differences for all ordinal level data including the NPRS, shoulder strength

Table 5. *Interaction effect between experimental and control groups at week 3, week 6 and 6-month time points. Positive values indicate higher scores in the experimental group with negative values indicating higher scores in the experimental group.*

Outcome measure	3 weeks	p value	6 weeks	p value	6 months	p value
GROC	NA	NA	-0.8	0.29	-0.12	0.88
Best Pain NPRS	1.1	<.001	0.55	0.12	0.91	0.02
Average Pain NPRS	1.24	0.03	1.71	<.001	1.44	0.02
Worst Pain NPRS	1.41	0.03	2.51	<.001	2.05	0.006
ERS	-0.03	<.001	-0.04	<.001	-0.04	<.001
IRS	-0.02	0.11	-0.02	0.12	-0.03	0.02
AbdS	-0.01	0.38	0.02	0.12	0.04	<.001
ABD/ER SR	0.16	0.05	0.19	0.02	0.11	0.22
IR/ER SR	0.1	0.23	0.17	0.04	0.14	0.13
Medial UQYBT	-0.07	0.2	-0.09	0.1	-0.07	0.22
Superior/ Lateral UQYBT	-0.05	0.17	-0.05	0.25	0.01	0.82
Inferior / Lateral UQYBT	-0.04	0.28	-0.04	0.25	0.02	0.63
Flexion AROM	-1.18	0.83	0.75	0.89	0.69	0.91
Abduction AROM	-6.84	0.33	-8.56	0.23	-8.41	0.29
ER AROM	-1.61	0.64	-4.96	0.15	-4.23	0.27
IR AROM	-1.31	0.72	-4.58	0.21	-5.05	0.22

Note: Results describe the interaction coefficient derived from a multilevel hierarchical model accounting for repeated measures.

GROC= global rating of change scale; NPRS= numeric pain rating scale; NA= not applicable; ERS= external rotation strength; IRS= internal rotation strength; AbdS= abduction strength; ABD/ER SR= external rotation abduction strength ratio; IR/ER SR= external rotation internal rotation strength ratio; AROM= active range of motion; ER= external rotation; IR= internal rotation; UQYBT= upper quarter Y-balance test.

ratios, and WORC. The interaction coefficient derived from a multilevel hierarchical model accounting for repeated measures was utilized for between and within group measures at all time points (beginning of the study, week 3, week 6, and at 6-month follow up). Post hoc testing for pairwise comparisons were performed using a Tukey correction.

RESULTS

Seventy-one individuals were recruited over 18 months. Seven were ineligible to participate due to medical screening exclusions, confirmed rotator cuff tears, or adhesive capsulitis. Sixteen individuals failed to meet the physical examination inclusion criteria of three positive SAPS tests. After randomization, the ETER group included 25 individuals (10 women and 15 men), while the GE group included 23 individuals (10 women and 13 men) (Figure 2). Descriptive statistics are provided in Table 2. Two participants requested to cease participation before the week three follow-up and 10 did not return phone calls to schedule the 6-month data collection time points, resulting in a total participant retention rate for the 6-month follow up at 75% (9 missing from GE group and 3 from ETER group). Individuals who did not return for the 6-month follow up were contacted two times by telephone to improve retention. Demographic data and week six primary and secondary outcome measure results were compared between the participants who chose to cease participation and those who returned for the 6-month follow up without any significant within group difference identified. Due to the asymmetric attrition between the GE and ETER group intention to treat analysis was not utilized to prevent a potential Type I error. Participants that were retained in the study did not demonstrate a significant difference between groups for home program adherence.

Table 3 provides mean and standard deviation values for all outcome measures at the baseline, 3 -week, 6 –week, and 6 -month follow up time points. Table 4 provides pairwise comparisons of mean differences for the primary outcome WORC scores at week 3, week 6 and 6-month time points. A significant difference ($p < 0.007$) favoring the experimental group was identified across all time points for the primary outcome of self-report function as measured by the WORC. The interaction effect for the secondary outcome measures at all time points is described in Table 5. After three weeks only NRPS ($p < 0.03$) and ERS ($p < .001$) displayed a statistically significant interaction effect. Upon the conclusion of treatment at week six, a significant interaction for average and worst NPRS values ($p < .001$), ERS ($< .001$) and the external rotator to abductor and external rotator to internal rotator strength ratios ($p < 0.04$) were identified. After six months secondary outcome measures were improved for pain on average and pain at worst as measured by the NPRS ($p < 0.02$), external rotator, internal rotator and abductor strength ($p < 0.02$). The secondary outcome measures of GROC, AROM, UQYBT and strength ratios were not statistically significantly different in the multilevel model after six months.

DISCUSSION

The primary objective of this study was to investigate if individuals with SAPS would benefit from a six-week protocol of ETER compared to a group of individuals who performed a GE program. Based on these results. it can be concluded that pain levels, participant reported function, and external rotator strength were significantly improved for individuals with SAPS after six weeks of treatment. Six months after an ETER protocol pain levels, participant reported function, external rotator, abductor, and internal rotator strength measures were significantly improved. The changes experienced by the intervention group were superior to those seen in participants who underwent a GE program (control group).

Significant improvements in the mean body weight adjusted external rotation strength was demonstrated by comparing the baseline value of .133 to three weeks mean measures of .153, six week measures of .156 and six month measures of .171 in the ETER group. Contributing factors to the increase in strength after only three weeks in this study could possibly be attributed to short-term neurological changes (e.g. rate coding and motor unit recruitment). Strength improvements are often correlated with increases in muscle hypertrophy and cross sectional muscle size after long term exposure to training, most commonly occurring after eight weeks.[42] Long-term strength changes can also be attributed to improvements in tendon stiffness which has been

documented to occur after 14 weeks of training.[43] Exercise training has a positive effect on motor unit recruitment and could reverse the effects on muscular strength inhibition in the injured population of individuals, in a relatively short period of time.[44] The authors are unable to make a suggestion regarding why the strength improvements were achieved as muscle hypertrophy and neurological mechanisms were not measured.

A comparison of these results to the prior experimental studies examining eccentric training for SAPS reveal similar reductions in pain and improved function.[12,13,17] Bernhardsson et al.[14] reported visual analog scale (VAS) improvements from 57 to 29mm before and after 12 weeks of eccentric shoulder training. The results reported by Bernhardsson et al.[14] are comparable to the results of the current study for average pain improvement after training. However, Bernhardsson et al.[14] recruited individuals with at least one year of chronic shoulder pain and resting VAS scores of at least 30 mm. It appears that Bernhardsson et al.[14] had a sample of individuals with more severe pain levels upon initial examination whereas the sample in this study had mean initial ratings of 3 and final ratings of 0 for average pain.

The WORC was utilized to measure participant reported shoulder function. A significant between group difference was identified ($p < .007$) from the baseline mean score of 66.63%, week 3 score of 82.10%, week six score of 87.6% and six-month score of 92.72% for the ETER group. The MCID for the WORC has been reported to be 13%.[45] These results identified a 26.09% improvement for the ETER group which exceeded MCID compared to the 11.75% change in the GE group which did not exceed established values for MCID. Prior investigations on shoulder eccentric training utilize a variety of patient report functional measures. This study utilized the WORC because it is a disease specific tool unique to individuals with SAPS and rotator cuff tendinopathy.

Blume et al.[17] did not identify a significant between group difference for pain and function when comparing an eccentric only shoulder protocol to a traditional isotonic program for individuals with SAPS. It should be noted that the Blume et al.[17] study utilized equal levels of resistance for each group. This lack of appropriately prescribed heavy load resistance is contrary to the purpose of eccentric training which should utilize loads that cannot be performed concentrically. The benefit of eccentric training is that the heavier resistance could provide tendon remodeling and hormonal changes that benefit the nervous, endocrine and musculoskeletal systems.[46,47]

An important feature of this exercise protocol was that pain was not reproduced during the interventions. Participants were asked to conduct exercises without increasing symptoms which is in direct contrast to the prior investigations for shoulder eccentric training.[21] Another difference identified in this study is the use of eccentric training with a maximal load that is progressed based upon the individual's ability to increase the number of repetitions performed. Utilizing an achieved repetition based progression could have a greater benefit for rotator cuff strength gains compared to a symptom reproducing system of advancement. Finally, the emphasis on training the external rotators in isolation may have a greater biomechanical benefit in restoring function of the shoulder complex as the causative factor of external rotator cuff weakness has been attributed to SAPS.[48,49]

Study limitations

Study limitations include the possibility of including participants without an isolated rotator cuff tendinopathy diagnosis. The inclusion and exclusion criteria in this study were formulated according to those used in prior eccentric rotator cuff studies[12,13] but without advanced imaging technologies the diagnostic accuracy of these examination criteria may have been a limitation. Moreover, the generic control group interventions may not be generalizable to a typical exercise program utilized by an individual experiencing SAPS. Nevertheless the methodology from this study followed methods utilized in previous trials.[12,50] Another limitation could be the possibility of a Type II error for between group differences in GROC, strength ratios, the UQYBT, and AROM measurements. This investigation did demonstrate a lack of statistical power for several of these dependent variables and the relatively small sample size is a limitation. This investigation remains unique in that heavy load eccentric training to only the external rotators was utilized providing value for future studies.

Future research

The clinical examination and diagnosis of SAPS is critically important for future research. The variability in clinical presentation for SAPS likely influences outcomes and a classification system for patient subgrouping could be helpful to determine which patient characteristics respond most favorably to ETER. The prescription/dosage of exercise and progression should also be investigated in more detail. The dosing protocol utilized in this investigation of 3 sets of 15 for ETER was utilized in prior shoulder research but its origin could be considered arbitrary and developed from research studies conducted on the Achilles tendon.[51] A progressive protocol with varying dosing strategies based on symptom response and functional status would be more generalizable to clinical practice. Varying the speed, duration, and shoulder positions during ETER in comparison to traditional rotator cuff strengthening exercises should be investigated.

CONCLUSIONS

Shoulder pain, function, and rotator cuff strength improved significantly after a six-week ETER protocol for individuals with SAPS when compared to a control group performing a GE program. The experimental protocol emphasized training only the rotator cuff muscles responsible for external rotation and progressed participants based on strength improvements and not symptom reproduction. This symptom reducing exercise program may be of benefit to the rehabilitation programs for individuals experiencing SAPS. Moreover, focusing on the external rotators, as in this study, avoided painful impingement positions from overhead activity and did not perpetuate muscle imbalances (e.g. deltoid to rotator cuff) previously implicated in the etiology of SAPS. Lastly, the results of this study provide a basis for future research comparing different diagnoses as well as intervention groups.

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